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THE CLEVELAND MUSEUM OF NATURAL HISTORY

CLEVELAND, OHIO JANUARY 8, 1970 NUMBER 9

SOME ORNAMENTED ERISOCRINIDS FROM THE AMES LIMESTONE

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ABSTRACT

Three new species of erisocrinid inadunate crinoids from the Ames Limestone, Conemaugh Group, Pennsylvanian, are described. All are ornamented forms. *Delocrinus brookensis* sp. nov. from Brooke County, West Virginia, is more specialized than *Delocrinus tulsaensis* (Strimple) from the Desmoinesian of Oklahoma, but is probably a derivative of that species. *Endelocrinus pennsylvanicus* sp. nov. from Allegheny County, Pennsylvania, appears to be the largest Pennsylvanian representative of *Endelocrinus* and is also characterized by spine-bearing primibrachs. *Paradelocrinus decoratus* sp. nov. from Brooke County, West Virginia, in addition to being ornamented, is a relatively large species, but otherwise seems to be a fairly conservative member of the genus.

In a discussion that follows, the recent proposal by Knapp to remove from the Cladida forms with a dorsal cup having a basal concavity and include them in a new order, the Declinida, is opposed because adequate grounds for such action are not evident.

Ornamented crinoids representative of the family Erisocrinidae are fairly common in marine beds of the Conemaugh Group, Pennsylvanian, of the Allegheny region, and the three new species from the Ames Limestone described in the present paper represent only a few of the Conemaugh forms characterized by surface features such as nodes, granules, or a combination of the two. Unfortunately, ornamentation in many of these crinoids is quite variable, apparently undergoes modifications during ontogeny, and is often poorly preserved in fossil material. However, the specimens under description appear to represent mature forms, the ornamentation is fairly well preserved, and my specific distinctions are not based on ornamentation alone.

I wish to extend my appreciation to Mr. Bruce Frumker, staff photographer of the Cleveland Museum of Natural History, for the

SMITHSONIAN
FEB 11 1970

photographs from which the illustrations were taken, and to my wife, Emily A. Burke, for aid in preparation of the manuscript and arrangement of the illustrations.

SYSTEMATIC PALEONTOLOGY

Family ERISOCRINIDAE Miller, 1889

Genus **DELOCRINUS** Miller and Gurley, 1890

DELOCRINUS BROOKENSIS[1] sp. nov.

Fig. 1

Diagnosis: Dorsal cup in general resembling that of *Delocrinus tulsaensis* (Strimple) but larger (width 23.4 mm) and higher (form ratio .34) with deeper basal impression, less prominent nodose ornamentation, and anal X more reduced in size.

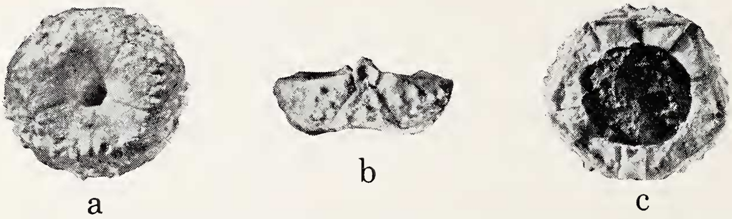

Fig. 1. *Delocrinus brookensis* sp. nov. Holotype, Cleveland Museum 3912, from the Ames Limestone, Conemaugh Group, Brooke County, West Virginia. *a*, dorsal view; *b*, posterior view; *c*, ventral view, ×1.

Holotype: Cleveland Museum of Natural History 3912, a complete dorsal cup.

Occurrence: Ames Limestone, Conemaugh Group, Upper Pennsylvanian.

Locality: Excavation (Tunnel Road Cut) for West Virginia Route 67 (lat. 40° 14′ 24″ N., long. 80° 35′ 53″ W.) near McKinleyville, Brooke County, West Virginia.

Repository: Cleveland Museum of Natural History, Cleveland, Ohio.

Description: The dorsal cup of this species is low, truncate bowl-shaped, and of medium size. In dorsal view the cup appears subround, in ventral view pentagonal. The basal impression extends somewhat beyond midheight and occupies about half the diameter of the cup.

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[1] Named for Brooke County, West Virginia.

None of the stem is preserved. The infrabasals slope downward steeply, and flare outward slightly. They extend for nearly three-fifths the height of the basal impression. Proximally the curvature of the basals is moderate, but distally, along the sides of the cup, the curvature is more abrupt. Within the basal impression these plates are gently concave transversely, and even slightly concave at the basal plane, but become gently convex distally. Except for the posterior basal, which is longer than wide, the basal plates are slightly wider than long.

The radials are slightly less than twice as wide as long, have fairly steep slopes, and are slightly convex along their length except for a sharp incurvature distally to form a moderate forefacet. These plates are broadly convex from side to side, contributing to the subround outline of the cup in dorsal view. The articular facets show denticles on the outer ligament areas and the transverse ridges, prominent oblique fossae and broad intermuscular notches.

Anal X is relatively small, about a fourth longer than wide, strongly incurved distally and slightly concave from side to side proximally. It bears a single distal facet for articulation with a second tube plate.

The major ornamentation consists of prominent nodes, the largest of which are arranged in a festoon-like row bordering the forefacet of each radial. Below these, scattered nodes occur on the radials and on those portions of the basals that are part of the lateral wall of the cup. In addition to the nodes, fine granular ornamentation is distributed over most of the cup, including the proximal portion of the basals.

Linear measurements of the holotype, in millimeters, are given in the table below:

Height of dorsal cup	7.9
Width of dorsal cup	23.4
Ratio of height to width	0.34
Height of basal impression	5.0
Width of basal impression	11.5
Length of basal (raB)	8.9
Width of basal (raB)	9.2
Length of radial (aR)	7.3
Width of radial (aR)	12.9
Length of suture between basals	6.0
Length of suture between radials	3.2
Length of anal X	4.8
Width of anal X	3.6

Remarks: As the diagnosis indicates, this species resembles *Delocrinus tulsaensis* (Strimple, 1962). It is probably a direct derivative of the Oologah species and as such may be taken as an indicator of the rate of evolution in this line of crinoids from Oologah to Ames time.

Knapp (1969) advocates that the generic name *Delocrinus* Miller and Gurley be treated as a *nomen dubium* and the name of the genotype species, *Poteriocrinus hemisphericus* Shumard, 1858, a *nomen nudum*. In support of these proposals he notes that Shumard's types have been lost, regards Shumard's description as inadequate and indicates that no described specimens subsequently assigned to the species agree with the original description. However, I am in agreement with Moore and Plummer (1940, p. 253) in feeling that "the essential characters of the genus and its validity are not in doubt." Furthermore, although the species is probably a rare one, I think that the description will prove adequate to distinguish it, if additional specimens are discovered. In any case, as long as there is a possibility that topotype material may be found, *Delocrinus hemisphericus* (Shumard) has claim as a valid species.

In a previous paper (Burke, 1966) I regarded Strimple's (1961) proposed genus *Graffhamicrinus* as a synonym of *Delocrinus*, because it was based on surface ornamentation, a feature insufficient for generic distinction. Knapp (1969) recognizes *Graffhamicrinus* as a genus but (p. 363) emends it to include several other species previously included under *Delocrinus* "in which the proximal tips of the radial plates are visible in side view, the cups may or may not be ornamented, and in which the first primibrachs, which are axillary, may or may not bear spines."

As thus emended, *Graffhamicrinus* does not appear to me to have any better claim to generic distinction than it had previously. In this connection it is interesting to note that the measurements given by Shumard (1858, p. 221) for *Delocrinus hemisphericus* indicate that the proximal tips of the radials of that species are visible in side view.

Genus **ENDELOCRINUS** Moore and Plummer, 1940

ENDELOCRINUS PENNSYLVANICUS sp. nov.

Fig. 2

Diagnosis: A large species, near *Endelocrinus texanus* (Weller) in size (width of dorsal cup .21 mm) but cup higher (form ratio .36) basal impression nearly twice as deep, walls steeper, and plates ornamented with nodes and granules. Primibrachs spinose.

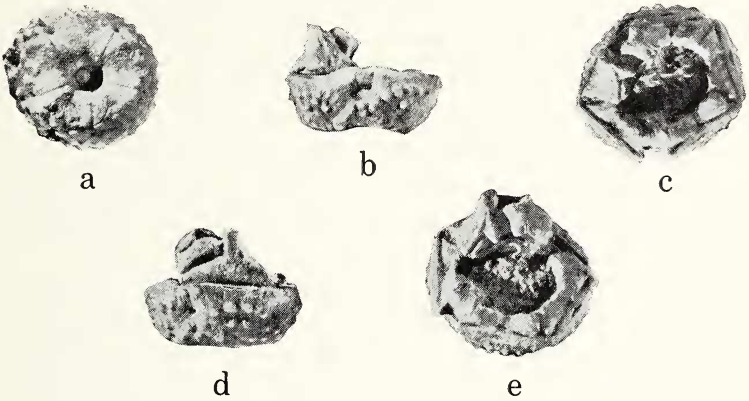

Fig. 2. *Endelocrinus pennsylvanicus* sp. nov. Holotype, Cleveland Museum 3913, from the Ames Limestone, Conemaugh Group, Allegheny County, Pennsylvania. *a*, dorsal view; *b*, posterior view; *c*, ventral view; *d*, E-ray view showing IBr$_1$, IIBr$_{1-2}$ (A ray on left); *e*, oblique ventral view showing articular facets of IBr$_1$ and IIBr$_2$, E ray, ×1.

Holotype: Cleveland Museum of Natural History 3913, a dorsal cup with the first primibrach and two secundibrachs of the E ray attached.

Occurrence: Ames Limestone, Conemaugh Group, Upper Pennsylvanian.

Locality: Excavation at Holiday Park (lat. 40° 27′ 46″ N., long. 79° 42′ 57″ W.) Plum Borough, Allegheny County, Pennsylvania.

Repository: Cleveland Museum of Natural History, Cleveland, Ohio.

Description: The dorsal cup is truncate bowl-shaped and of medium height. The vertical extent of the basal impression is nearly three-fifths the height of the cup, and the width of the impression is slightly less than two-fifths the width of the cup. The infrabasal circlet shows a pentalobate central canal within the stem impression. The infrabasals are steep-walled, occupy more than half the height of the basal impression, and flare outward to the extent that they would be visible if the stem were attached.

The basals are about one-sixth wider than long. They flare steeply outward and downward from the basal impression, but less so than the infrabasals. However, the steepest longitudinal slopes of the basals are in their proximal portions; the convexity in the midregion is slight, but the upward (distal) slope is fairly steep. These plates are strongly concave from side to side proximally. They continue to be concave from side to side, although much more gently, to their midregion and even beyond their proximal contact with the radials along the lateral wall of the cup. Beyond the steep wall of the basal impression the basal sutures are slightly impressed. The distal margins of the basals are gently curved. At all angles where the basals and radials meet, these plates are inflexed to form the characteristic *Endelocrinus* pits.

The ornamentation of the basals is of two types. One type consists of closely spaced rounded granules that cover the entire plate except for the steep wall of the basal impression. The other is in the form of coarse nodes that are confined to the distal part of each plate. The most proximal of these nodes are paired and shared by adjacent basals near the distal termination of each interbasal suture. The basal plane is tangent to the tips of these paired nodes.

The radials are a little more than two-thirds wider than long. They show slight convexity along their length, although each is rather abruptly incurved near the summit, forming a distinct forefacet. The transverse curvature is moderate and most pronounced about midheight. The ornamentation comprises nodes and granules similar to those on the basals. The forefacet is free of nodes, but there is a node at the lateral termination of each radial at the summit. Otherwise the radials bear no nodes closely adjacent to the interradial sutures.

The radial facets are relatively shallow. The outer ligament area is short and is denticulate in the region external to the slitlike ligament pit which occupies most of its extent. The transverse ridge extends essentially to the full width of the facet; it is fairly well defined and denticulate. The inner ligament fossae are rather deep and extend almost parallel to the transverse ridge to points nearly opposite the terminations of the outer ligament area. The oblique ridges are strong and denticulate. The intermuscular notch is quite broad and there appear to be indications of muscle areas flanking the intermuscular furrow. The lateral ridges face outward, but are relatively low. The adsutural slopes are gentle and the adsutural platforms extensive.

Anal X has been displaced; its distal end lies in the body cavity and the entire plate has shifted inward between the posterior radials. Proximally, anal X rested on the truncated tip of the posterior basal, and along with the basal and radials was inflexed to form a small pit on each side at the angles where it met those plates. For most of its height anal X is slightly concave from side to side. It bears a single distal facet for articulation with a second anal plate.

A single axillary first primibrach, that of the E ray, remains in place. It is more than twice as wide as long, and bears a short but distinct spine. In addition to granulose ornamentation similar to that of the dorsal cup, this plate bears a node on each lateral shoulder, below and flanking the spine.

The distal articular surface of the primibrach is divided into right and left facets by a prominent, partly denticulate ridge. The right facet is fully exposed. It shows an outer ligament area that is relatively longer and much less compressed than the outer ligament areas of the radials. This ligament area is denticulate. The external ligament pit is slightly elongate but not slitlike as in the radials. It does not occur at midlength of the ligament area, but is somewhat nearer the termination of the area in the vicinity of the ridge that separates the facets. A strong denticulate transverse crest is present, together with well-defined ligament fossae. Although most of the articulation appears to have been of the ligamentary type, structures on the inner side of the ridge that separates the facets strongly suggest muscle scars.

The first two secundibrachs of the left arm of the E ray are also present. The first secundibrach has been displaced outward, carrying the second with it. Both of these plates show granulose ornamentation. The first secundibrach bears a nodose swelling on the right side. The second secundibrach displays a large node or blunt spine in this region.

The first secundibrach is quadrangular and about three times as wide as long. Because of the position of the plate I have not been able to determine whether it bore a pinnule and interlocked with adjacent plates, although presumably it did.

The second secundibrach is quite low and elongate from side to side in external view. Because its lateral terminations are both angular, it is not a typical cuneate plate. Laterally, the plate shows structures for interlocking with plates of adjacent arms. These are especially evident as bulbous swellings on the left (pinnular) side. A pinnule socket is present on the internal side. The distal articular facet bears a prominent crenulated outer ligament area, traces of an outer ligament pit, and a transverse crest. The inner ligament area is more extensive on the left (pinnular) side, and extends inward and laterally in that region, rising up to a rounded prominence well above the rest of the articular surface. Along the outer border of this left side, but internal to the transverse crest, are additional crenulations.

The intermuscular notch of this second secundibrach is sharply angular and the intermuscular furrow originates near the transverse crest. The flexor muscle scar of the left (pinnular) side originates along the internal reaches of the intermuscular furrow and extends as a channel bordering the pinnular side of the intermuscular notch for about half the length of that side of the notch. The channel expands widely toward its termination.

The flexor muscle scar of the right (antipinnular) side of this second secundibrach is separated from the muscle scar of the pinnular side by the intermuscular furrow, and runs parallel to the latter to a point a little beyond the exit of the furrow. It is deeper than the scar on the pinnular side, but much less elongate.

To the right of the antipinnular muscle scar the articular surface is rounded, elevated, and bears crenulations suggestive of ligament attachment areas. From that place to the transverse ridge the antipinnular articular surface is concave and slopes gently laterad.

Linear measurements of the holotype specimen, in millimeters, are shown in the following tabulation:

Height of dorsal cup	7.5
Width of dorsal cup	21.0
Ratio of height to width	0.36
Height of basal impression	4.2
Width of basal impression	8.8
Length of basal (raB)	7.1
Width of basal (raB)	8.3
Length of radial (laR)	6.5

Width of radial (laR)	11.2
Length of suture between basals	5.4
Length of suture between radials	3.4
Length of anal X	4.4
Width of anal X	3.6
Length of first primibrach (E ray)	5.0
Width of first primibrach (E ray)	11.6
Length of first secundibrach (E ray)	2.5
Width of first secundibrach (E ray)	7.5
Length of second secundibrach (E ray)	1.8
Width of second secundibrach (E ray)	5.8

Remarks: In ornamentation, *Endelocrinus undulatus* (Strimple, 1961) bears resemblance to this species, although the nodes are apparently less prominent. In addition, *Endelocrinus undulatus* is a smaller species, the dorsal cup is relatively higher, the basal impression is wider, the primibrachs do not bear spines and both primibrachs and secundibrachs have greater height.

From the standpoint of size, *Endelocrinus pennsylvanicus* appears to be the largest Pennsylvanian representative of the genus.

Knapp (1969) would restrict *Endelocrinus* to two species, *Endelocrinus fayettensis* (Worthen) and *Endelocrinus bifidus* Moore and Plummer, characterized by gently downflaring infrabasals. He includes *Endelocrinus texanus* (Weller) in his proposed genus *Metarrectocrinus* for the same reason. He emends Strimple's genus *Tholiacrinus,* which as originally proposed, was considered synonymous with *Endelocrinus* by Burke (1966) and Webster and Lane (1967) because it was based solely on ornamentation, a feature insufficient for generic distinction. As emended by Knapp, the sole basis for distinction between *Endelocrinus* and *Tholiacrinus* would be steeply downflaring infrabasals, which he assumes to characterize *Tholiacrinus.*

Dorsal cups of *Endelocrinus* are distinguished by the characteristic pits at the angles where the radials and the basals meet, and usually by convexity or even bulbosity of these plates of the cup. These salient generic characters are shown in common by *Endelocrinus fayettensis, Endelocrinus texanus, Endelocrinus bifidus,* and the various species of *Endelocrinus* which Knapp would lump together under *Tholiacrinus.* There is no evidence that the degree of downflaring of the infrabasals modifies the dorsal cups of these species to the extent that the generic characters cited above are not evident. For this reason I regard *Tholiacrinus* as emended by Knapp to be a synonym of *Endelocrinus.*

Genus **PARADELOCRINUS** Moore and Plummer, 1938

PARADELOCRINUS DECORATUS sp. nov.

Fig. 3

Diagnosis: A relatively large species of *Paradelocrinus* (width of dorsal cup 25.7 mm); form ratio .37; cup pentagonal in ventral view; basal impression deep and about half as wide as the cup; basal plates concave from side to side at basal plane; basals and radials ornamented with fine ridges and prominent nodes.

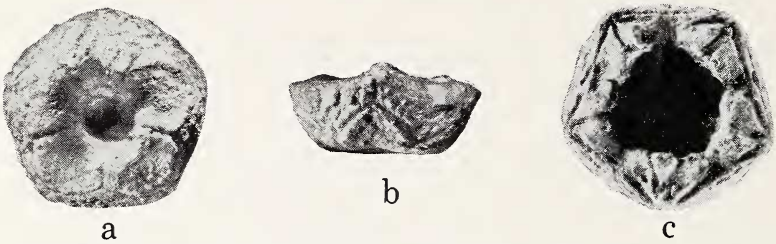

Fig. 3. *Paradelocrinus decoratus* sp. nov. Holotype, Cleveland Museum 3914, from the Ames Limestone, Conemaugh Group, Brooke County, West Virginia. *a*, dorsal view; *b*, posterior view; *c*, ventral view, ×1.

Holotype: Cleveland Museum of Natural History 3914, a dorsal cup complete except for the infrabasal circlet.

Occurrence: Ames Limestone, Conemaugh Group, Upper Pennsylvanian.

Locality: Excavation (Tunnel Road Cut) for West Virginia Route 67 (lat. 40° 14′ 24″ N., long. 80° 35′ 53″ W.) near McKinleyville, Brooke County, West Virginia.

Repository: Cleveland Museum of Natural History, Cleveland, Ohio.

Description: The dorsal cup is low, truncate bowl-shaped and nearly three times wider than high. It is subpentagonal in dorsal view and pentagonal in ventral view. The basal impression occupies about half the diameter of the cup. The impression was evidently quite deep, but the infrabasal circlet, which represented about one-seventh of the cup diameter, is missing and the full height of the impression cannot be determined.

The basal plates comprise most of the base of the cup; their distal tips extend for more than half the height of the radials. All of the basals, including the posterior basal, which is longer than the others, are pentagonal in outline. These plates curve rather strongly upward into the basal impression proximally; distally, beyond the basal plane, they again curve upward, but more gently. Each basal plate is also a little concave from side to side. The basal plane in consequence, is tangent to points along the basal sutures, but a gentle concavity characterizes these plates distally, well above the basal plane. The distal margins of the basals are rounded to the tips, rather than angular.

Each of the radial plates is pentagonal in outline and nearly twice as wide as high. In keeping with the longer posterior basal plate, the suture between the two posterior radials is shorter than the other interradial sutures. Proximally the radials slope outward and upward with little convexity, retaining the distal slope of the basals. Toward the summit of the cup the radials become a little more convex from side to side, and more convex along the length, just below the outer ligament area.

The articular facets of the radials are of medium depth. The outer ligament area is narrow and elongate, with a slitlike outer ligament pit. The transverse crest extends to the lateral extremities of the facet and is denticulate. In the inner ligament area the lateral furrows are elongate and rather narrow and the oblique ridges are denticulate. The adsutural slopes are abrupt and the adsutural platforms wide. The lateral ridges slope outward fairly strongly. The intermuscular notch is broad, leading into a short intermuscular furrow. A broad, low, concave region, representing the two muscle areas, is bordered by the notch and divided by the furrow.

Anal X is entirely shut off from the outer side of the cup by the posterior radials, which share a CD interradial suture on that side. At the summit of the cup the left lateral corner of the C radial is slightly elevated and bent inward. At the termination of this prolongation of the radial corner, anal X fits between the lateral ridges of the adjacent posterior radials. In ventral view the plate is triangular in outline; it widens as it approaches the body cavity and rises above the inner articular surfaces of the radials. Its ventral surface bears a facet for articulation with a second anal plate.

The ornamentation is of two kinds, the most prominent consisting of nodes on the radials and the basals. On the radials the nodes are arranged in three rows. The proximal two rows tend to parallel the sutures between the radials and the basals. The distal row is somewhat transverse and the nodes are larger than those of the proximal rows. There is also a row of nodes on each basal, which borders the sutures between the radials and the basals, and nodose swellings border the interbasal sutures distally. Irregular nodes are also distributed over the portions of the basals that rise above the basal plane. The sutures are not impressed, but where nodes border the sutures they appear to be.

A second, finer kind of ornamentation comprises wrinkles or ridges on the basals and the radials. These ridges also extend across the nodes, where in general they show an arrangement at right angles to the sutures. The wrinkled ornamentation persists part way into the basal impression.

Linear measurements of the holotype, in millimeters, are as follows:

Height of dorsal cup	9.5
Width of dorsal cup	25.7
Ratio of height to width	0.37
Width of basal impression	10.8
Length of basal (raB)	9.5
Width of basal (raB)	9.9
Length of radial (aR)	7.6
Width of radial (aR)	15.5
Length of suture between basals	7.1
Length of suture between radials	4.3
"Length" of anal X	5.3
Width of anal X	3.3

Remarks: In comparison with the genotype species, *Paradelocrinus aequabilis* Moore and Plummer, 1938, *Paradelocrinus decoratus* appears to be a fairly typical representative of the genus. It is, of course, a much larger species than *Paradelocrinus aequabilis,* the cup is higher, the basals are more prominent, and the cup is ornamented. Nevertheless, in the outward flare of the cup walls, deep basal impression and appearance of anal X, it is closer to *Paradelocrinus aequabilis* than many other forms that have been referred to *Paradelocrinus.*

There are some resemblances between *Paradelocrinus decoratus* and *Paradelocrinus planus* (White, 1880) in cup height, depth of basal impression, and size of basal circlet, but the cup of *Paradelocrinus decoratus* is larger, more pentagonal, and ornamented rather than smooth.

In ventral view, *Paradelocrinus iolaensis* Strimple, 1949, is reminiscent of *Paradelocrinus decoratus* in its pentagonal outline and appearance of anal X. The basal plates of *Paradelocrinus iolaensis* are concave from side to side in the vicinity of the basal plane, but more concave than those of *Paradelocrinus decoratus.* The dorsal cup of Strimple's species is also smaller, of lesser height, more pentagonal in dorsal view, and unornamented.

The Atokan species described by Knapp (1969) as *Atokacrinus obscurus* is likewise similar to *Paradelocrinus decoratus,* although the dorsal cup is not as high. The dorsal cup of the Knapp type is worn, and may have borne ornamentation, but the flattened depressed areas that bound the sutures do not characterize the cup of *Paradelocrinus decoratus.* Like those of *Paradelocrinus decoratus,* the basals of Knapp's species are concave from side to side at the basal plane.

In proposing *Atokacrinus* as a new genus, Knapp gives for a diagnosis "Basal concavity deep, infrabasals steeply downflared." Knapp has also proposed a new genus, *Sublobalocrinus,* to include *Paradelocrinus iolaensis* and *Paradelocrinus planus,* based on the following diagnosis: "Basal concavity narrow and deep; infrabasals steeply downflaring, basals transversely concave; arms unknown."

Like *Paradelocrinus aequabilis* and *Paradelocrinus decoratus,* the species comprising Knapp's proposed new genera are fairly conservative forms, which, except for the characteristic curvature of the cup in lateral view and absence of anal X from the outer side of the cup, strongly resemble the dorsal cups of various species of *Delocrinus.* For such forms, Knapp's generic characters might have specific, but not generic weight, and I regard *Sublobalocrinus* and *Atokacrinus* as synonyms under *Paradelocrinus.*

DISCUSSION

This article was essentially completed before the appearance of Knapp's (1969) paper dealing with his proposed new order Declinida. As a consequence some revision was necessary in order to deal with new taxa introduced by Knapp and various taxonomic changes which he advocates. I feel obligated to summarize certain of my views concerning the content of Knapp's paper, however, since I fail to find justification for the establishment of the Declinida as a new order.

Knapp (ibid. p. 343) contends that in the Inadunata, downflaring infrabasals cannot have evolved from infrabasals that were originally upflaring, and states: "With the infrabasals established as a stable element in the dorsal cups of crinoids having anal X and radianal plates, the stage was set for the origin of a basal concavity having steeply downflaring infrabasals. The origin of steeply downflaring plates can be envisioned by reference to the position at which the infrabasal plates appear in the early growth stages of Recent crinoids, that is, deep within the basal circlet and steeply flaring. Rather than moving down from within the basal circlet as in Recent crinoids and presumably inadunates incorporating upflaring infrabasals, the infrabasal plates remained deep within the basal circlet and a basal concavity was created in fossil inadunates. As in fossil inadunates possessing upflaring infrabasal plates, evolution proceeded from steeply downflaring infrabasals to horizontal infrabasals and a flat base."

Knapp's theory that the basal concavity and downflaring infrabasals originated in the larval stage is a novel one, to say the least. Such major evolutionary changes are usually developed in gradual stages over long periods of time, and are traceable in adult forms. However, it may be questioned whether the larvae of modern crinoids, which share the extreme specialization of the adult forms, can be taken as indicators of an evolutionary sequence such as Knapp outlines.

In *Antedon adriatica* Clark (1921, p. 414), in a summary of Seeliger (1893) reports that at the earliest larval stage at which the infrabasals are found, they are anterior to the basals. On the other hand, Mortensen (1920, p. 26, pl. 12, fig. 3) finds the first detected infrabasal plate of *Compsometra serrata* lying within the basal circlet. But it is not until later stages, when the infrabasals are surrounded by the faster growing basal plates that they can be described as "deep within the basal circlet and steeply flaring." I fail to find evidence to support Knapp's view that the basal concavity of inadunates arose as a spontaneous development in the larval stage.

Knapp (1969, p. 351) stipulates that for inclusion in the Declinida the crinoid must possess what he terms a "structural" basal concavity—the infrabasals must flare downward. I gather from this that if the walls of the concavity were composed of the basals and were topped by a horizontal infrabasal circlet, an inadunate showing such a concavity would be excluded from the Declinida. However, it is evident that if the one type of concavity could have arisen in the larval stage, the other could have also.

It appears far more likely that the stages in evolution from upflaring to flat and finally to downflaring infrabasals illustrated by Moore, Lalicker and Fischer (1952, p. 624) represent the true course of change in attitude of these plates, rather than that suggested by Knapp. The latter writer quite apparently holds no brief for the derivation of downflaring from flat infrabasals. Attributing the decrease in steepness and flare and eventual "horizontality" of the radial and basal plates of *Antedon* to differential accretion of calcite during growth, Knapp (1969, p. 343) contends that these plates cannot change their horizontal attitude, once it has been attained, by accretion of calcite at their lateral margins. At this "horizontal" stage the plates are probably joined by zygosynostosial articulations, which, as Van Sant (1964, p. 39) states, are mostly immovable.

Now it is true that such articulations could prevent horizontal infrabasal plates from progressing to a downflaring attitude, and indeed zygosynostosial articulations appear to characterize the adjacent sides of flat infrabasal plates of various Upper Carboniferous inadunates. However, I have observed specimens of *Polusocrinus, Aesiocrinus, Parulocrinus* and *Ethelocrinus* in which individual plates are separated from others in the circlet or shifted from sutural position in such a manner as to suggest very slight calcareous deposits and the probability that at early stages of growth they were bound together by connective tissue only.

It seems reasonable to me that a similar very loose sutural union bound together the infrabasal plates of inadunates during the evolutionary transition from upflared to downflared plates that produced the basal concavity. Probably in early stages of growth the circlet remained flat and was supported at the center by the stem, but with the increase in weight of the expanding dorsal cup the infrabasals sagged downward, extending below the top of the stem peripherally, thus giving rise to the basal concavity. Calcite deposition may have been arrested up to this point; the height of the concavity in that case probably depended on (1) the rate of renewed calcite deposition leading to zygosynostosial articulation and

(2) the rate of upgrowth, if any, of the proximal portions of the basals.

Upgrowing basals probably influenced the angle of flare of the downflaring infrabasals before zygosynostosial articulations developed. Apparently synostosial articulation was not unusual between the basals and infrabasals of some Upper Carboniferous inadunates. In some species of *Delocrinus,* where such articulations occur, a slender flange at the proximal tip of each basal inserts into a short notch in the infrabasal circlet, preventing the closure of the infrabasal suture at that place. This indicates that prior to the time that the infrabasals were united by close suture they were separated, to some extent at least, by the basal tips. It would appear that in such specimens, if there is any possibility that the infrabasals are not yet joined by close sutures, it would be unwise to assume that the angle of flare of the infrabasals was stabilized and representative of the particular species involved.

If the infrabasal circlet had remained flat, and was bound to the proximal portions of the upcurving basals by loose suture, the continued growth of the basals would have resulted in their forming the walls of the basal concavity, with the infrabasal circlet roofing the concavity. This is the type of basal concavity found in *Plummericrinus.* Since from a mechanical standpoint such a concavity seems to have served the same purpose as one with downflaring infrabasals, I fail to see why Knapp considers the distinction between the two of major taxonomic importance.

Obviously I do not agree with Knapp that evolution of the taxa he includes in the Declinida proceeded from downflaring infrabasals to horizontal infrabasals and a flat base. Of course it is possible, because all stages are represented in the sequence from flat base to steeply downflaring infrabasals, to juggle various species of Upper Carboniferous inadunates into groups arranged in chronological order supposedly illustrating the reverse of that sequence. But many of these species are based on single specimens, and few are represented by an adequate number of individuals to determine extent of variation within a species, or to permit ontogenetic studies. Such being the case, to assume constancy in the angle of flare of the infrabasals in such species is not justified.

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MANUSCRIPT SUBMITTED DECEMBER 15, 1969